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ENERGY SAVINGS FACTORS & CONVERSIONS FOR POCKET REFERENCE BOOKLET

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Fuel energy conversions, heating system efficiencies and retrofit energy savings factors are confirmed, expanded and newly developed, respectively, for the new edition of a pocket reference booklet.

INTRODUCTION

Residential Marketing requested verification or revision of the heating fuel conversion factors, heating fuel efficiencies and energy savings factors, preparatory to publishing a replacement for the "REAP Conversion and Energy Savings Factors" pocket reference booklet. Customer Service staff use this guide for quick reference, so that simplicity of presentation and use are of the essence.

HEATING FUEL CONVERSIONS AND EFFICIENCIES

Table 1 gives the conversions between fuels, based on their full heating values (see Table 2), to two significant figures (references are indicated in the tables). These values do not incorporate equipment efficiencies, because of the wide range presently available. To compare heating system inputs that give the same output, ie the same energy delivered to the house, requires incorporation of the typical seasonal efficiencies listed in Table 3. This table has been expanded to include higher efficiency fossil fuel equipment, wood heaters and heat pump devices. If further simplification is needed, the values for the fossil fuels fall into four rough categories, independent of fuel type:

conventional	improved	mid-efficiency	high-efficiency
60%	70%	80%	90%

The use of Tables 1 & 3 is clarified with an example: how much natural gas in a high-efficiency furnace would give the same output as 3100 L of oil in a conventional furnace?

new fuel amount	=	old fuel amount	x	conversion factor from old to new (Table 1)	x old efficiency / new efficiency (Table 3)

= 3100 x 1.04 x 60 / 90
= 2100 cubic metres (note that only two significant figures are justified)

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INSULATION UPGRADE ENERGY SAVINGS FACTORS

The original factors in the REAP booklet were calculated using a degree-day formula without a C-factor (to account for marginal changes), but with an 80% factor for workmanship, etc. Building component heat losses will not follow this simple formulation because of the effects of internal waste heat utilization, solar gains, below grade tempering, etc. Also, newly standardized component resistance values are available from CSA Standard F280-M1986/1/. The microcomputer program, HOT-2000/2/, allows straightforward energy calculations based on a month-by-month analysis. Typical houses (see Appendix for a thermal description) were run with varying component insulation levels that are representative of conventional construction and usual upgrades. The changes in annual energy consumption, normalized by the component surface area, are presented in Table 4 for the Metropolitan Toronto area. These values do not include any provision for inferior workmanship, etc; this is discussed further below.

The sensitivity of the numbers in Table 4 to various parameters were investigated. Table 5 shows the effect of different styles and sizes of house. The Appendix describes the typical houses considered. The range of results is quite small, except for the case of windows, where a 10% effect is seen. Even that value is not large considering the use to which these factors are to be put. Note that the window factors are averaged over all orientations. Savings will be well estimated if all windows are replaced unless the windows are very unevenly distributed on the house's four faces. The effect of orientation was not studied but may be significant. Table 6 shows the effect of changing indoor temperature setting. In general, warmer temperatures yield larger savings (up to 10% larger for the basement improvement). But the window retrofit shows a slight decline, probably the result of a combination of decreased solar gain and increased utilization. The one caveat is that savings will be overestimated for those houses which are operated significantly colder than 20°C.

The only parameter which gives a significant variation in the energy savings factors is weather (climate severity). Table 7 documents the results for 13 Ontario locations. Figure 1 shows the results for the wall cavity retrofit on a provincial map. These variations are too large to ignore. The simplest method to account for weather is to ratio the factors by standard (base 18°C) degree-days. This is also shown in Table 7. For wall retrofits (and, it is expected, ceilings too), the degree-day correction is good to within 5%. The variations in ground temperatures give 15% excursions from the Toronto "norm" for basement upgrades. Similarly, solar radiation variations give up to 10% differences from Toronto for window retrofits. Although not perfect, the degree-day correction seems simple and adequate for the purpose of getting decent savings estimates throughout the province.

The savings from retrofits previously presented assume full realization of the predicted energy effect; this is probably not a good assumption on which to base estimates to customers of upgrading effects. Physical constraints in the particular home, workmanship difficulties, changes in occupant behaviour in reaction to the retrofit, etc, tend to decrease the actual savings from those predicted. It may thus be prudent to include a conservative factor (such as the 80% factor incorporated in the values presented in the previous REAP booklet) in the annual energy savings factors that are ultimately published. Such a factor will also tend to obviate the need to explicitly correct for the small variations due to such parameters as house style, size, etc.

When these energy savings factors are used in the field, there will be instances in which the total savings from a specific retrofit are too modest to justify, on a cost saving basis, the capital expense involved (eg window replacements). There may still be a case to be made for such

retrofits based on increased comfort or other amenity whose benefit is not easily quantifiable. Strict economic benefit using the savings factors should not become a necessary condition for upgrading suggestions to customers.

CONCLUSION

In support of the publication of a new pocket reference booklet for residential customer service representatives:

- conversion factors for the energy content of different fuels have been confirmed;
- heating system efficiencies have been expanded;
- new annual retrofit energy savings factors have been developed.

RECOMMENDATION

It is recommended that

- the heating fuel conversions in Tables 1 and 2,
- the heating system efficiencies in Table 3,
- and the annual energy savings factors in Table 4 (possibly discounted as discussed above, and using the simple degree-day correction for weather variations),

be used as the basis for relevant sections of the revised pocket reference booklet.

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REFERENCES

(See Tables 2 and 3 for specific references for the data presented in them)

1. Canadian Standards Association, Standard CAN/CSA-F280-M86, "Determining the Required Capacity of Residential Space Heating and Cooling Appliances", July 1986

2. HOT-2000, available from Energy Analysis Software, P O Box 7081, Postal Station J, Ottawa, Ontario K2A 3Z6

Table 1

DIRECT CONVERSION FACTORS

These are used to convert equivalent quantities of fuel based on their full heating values only (see Table 2) and not heating system efficiencies (but see Table 3).

To Convert From	To	Multiply by
Natural gas, ccf	No. 2 Fuel oil, gallon	0.60
Natural gas, cu. m	No. 2 Fuel Oil, litre	0.96
Natural gas, ccf	Electricity, kWh	29.
Natural gas, cu. m	Electricity, kWh	10.4
Natural gas, ccf	Liquid propane, gallon	0.88
Natural gas, cu. m	Liquid propane, litre	1.41
No. 2 Fuel oil, gallon	Natural gas, ccf	1.66
No. 2 Fuel oil, litre	Natural gas, cu. m	1.04
No. 2 Fuel oil, gallon	Electricity, kWh	49.
No. 2 Fuel oil, litre	Electricity, kWh	10.8
No. 2 Fuel oil, gallon	Liquid propane, gallon	1.46
Now. 2 Fuel oil, litre	Liquid propane, litre	1.46
Electricity, kWh	Natural gas, ccf	0.034
Electricity, kWh	Natural gas, cu. m	0.096
Electricity, kWh	No. 2 Fuel oil, gallon	0.020
Electricity, kWh	No. 2 Fuel oil, litre	0.093
Electricity, kWh	Liquid propane, gallon	0.030
Electricity, kWh	Liquid propane, litre	0.135
Liquid propane, gallon	Natural gas, ccf	1.14
Liquid propane, litre	Natural gas, cu. m	0.71
Liquid propane, gallon	No. 2 Fuel oil, gallon	0.68
Liquid propane, litre	No. 2 Fuel oil, litre	0.68
Liquid propane, gallon	Electricity, kWh	34.
Liquid propane, litre	Electricity, kWh	7.4

Table 2

FULL HEATING VALUE OF FUELS[a,b]
USING 3412 BTU/kW·h

Natural Gas[c]	1010	BTU/ft^3	10.4 kW·h/m^3
No. 2 Fuel Oil[d]	168000	BTU/gal	10.8 kW·h/L
Propane[a]	22000	BTU/lb	13.9 kW·h/kg
as liquid	115000	BTU/gal	7.4 kW·h/L
as gas	3200	BTU/ft^3	33. kW·h/m^3
Kerosene[b]	167000	BTU/gal	10.8 kW·h/L

References

[a] ASHRAE Handbook 1985 Fundamentals, Chapter 15
[b] EMR, quoted in Energy Management Canada, August/September 1982
[c] Consumers' Gas average analysis, 1985
[d] OHRD analysis, 1982

Table 3

TYPICAL SEASONAL EFFICIENCIES
OF VARIOUS SPACE HEATING SYSTEMS[a,b]

Electric	
resistance (unitary or central, forced air or hydronic)	100
radiant heating	95
all-electric air-source heat pump system	180
ground-source heat pump system	240
add-on air-source heat pump (replacing 60% of back-up fuel)	220
bivalent heat pump (replacing 88% of back-up fuel)	190
Natural Gas or Propane	
conventional furnace/boiler with pilot	60
conventional furnace/boiler with spark ignition	63
conventional furnace/boiler with spark ignition, vent damper	69
induced draft fan furnace/boiler	80
condensing or pulse furnace/boiler	90
Oil	
conventional furnace/boiler	60
conventional furnace/boiler with flue vent damper	64
conventional furnace/boiler with flame retention head	70
mid-efficiency furnace/boiler (no dilution air)	82
condensing furnace/boiler (no chimney)	90
Kerosene	
Unvented Heater[c]	100
Wood	
airtight wood stove	55
airtight wood stove with catalytic converter	65
wood/solid fuel furnace	45

References

[a] HOT-2000 Technical Documentation, July 1987
[b] A.C.S. Hayden, Canadian Combustion Research Laboratory, May 1983
[c] A.C.S. Hayden, private communication, January 1988

Table 4

ANNUAL ENERGY SAVINGS FACTORS FOR INSULATION UPGRADES
IN A TYPICAL HOUSE IN THE TORONTO AREA
(undiscounted HOT-2000 results for 100% efficient heating system)

Building Component	Upgrade	Nominal* Insulation Level (RSI) or Description		Annual Energy Savings Factor ($kW \cdot h/(m^2 \cdot a)$)
		Before	After	
Frame Wall	Fill cavity	0	1.4	75
		0	2.1	88
		1.4	2.1	13
	Add semi-rigid exterior insulation	1.4	2.5	19
		2.1	3.0	12
		1.4	2.9	24
		2.1	3.4	16
Masonry Wall	Add rigid exterior insulation	0	0.9	144
		0	1.8	173
Windows	Add glazings	single	double	222
		single	triple	305
		double	triple	84
Door	Add storm	panel wood	wood/storm	69
	Replace with metal insulated	wood/storm	polystyrene	74
		wood/storm	polyurethane	105
Flat ceiling	Add insulation	1.4	4.9	45
		1.4	7.0	53
		2.1	5.6	25
		2.1	7.0	28
		3.5	7.0	15
Cathedral Ceiling	Add insulation	0	2.1	101
		0	3.5	116
		1.4	2.1	19
		1.4	3.5	34
		2.1	3.5	15
Exposed Frame Floor	Add insulation	0	4.9	64
		1.4	4.9	26
		2.1	4.9	14
Slab on Grade	Add perimeter insulation	0	0.9	45 kW.h/(m·a)

Table 4 (Continued)

Building Component	Upgrade	Height Above Grade (m)	Annual Energy Savings Factor ($kW \cdot h/(m^2 \cdot a)$)
Full Depth Basement Wall (10" Block)	Add to uninsulated wall, extruded polystyrene insulation:		
	RSI 0.9	0.3	55
		0.6	69
		0.9	84
		1.2	100
	RSI 1.8	0.3	70
		0.6	87
		0.9	104
		1.2	122
Shallow Basement Wall (10" Block)	RSI 0.9	1.5	129
		1.8	132
		2.1	136
	RSI 1.8	1.5	154
		1.8	159
		2.1	163

*not total component resistance

Table 5

EFFECT OF HOUSE STYLE, SIZE
(Toronto Weather)

Retrofit	Annual Energy Savings Factor ($kW \cdot h/(m^2 \cdot a)$)		
	Bungalow	2-Storey	Big Bungalow
Wall Cavity, 0 to 2.1 RSI	88	88	91
Window, single to double	222	198	214
Basement 0.6 m above grade, 0 to 0.9 RSI	69	67	68

Table 6

EFFECT OF INDOOR TEMPERATURE SETTING
(Bungalow, Toronto Weather)

Retrofit	Annual Energy Savings Factor ($kW \cdot h/(m^2 \cdot a)$)	
	20°C (18°C basement)	21°C (19°C basement)
Wall Cavity, 0 to 2.1 RSI	88	93
Window, Single to double	222	215
Basement 0.6 m above grade, 0 to 0.9 RSI	69	75

Table 7

EFFECT OF WEATHER
(Bungalow)

Location	Annual Energy Savings Factor ($kW \cdot h/(m^2 \cdot a)$)			Degree-Days	Factor x100/Degree-days		
	Wall Cavity, 0 to 2.1 RSI	Window, single to double	Basement 0 to 0.9 RSI	(base 18°C)	Wall	Window	Basement
Big Trout Lake	162	145	115	7680	2.11	1.89	1.50
Timmins	130	122	91	6189	2.10	1.97	1.47
Thunder Bay	121	101	85	5746	2.10	1.76	1.48
Sudbury	115	112	86	5447	2.11	2.06	1.58
North Bay	113	103	85	5318	2.12	1.94	1.60
Sault Ste Marie	108	93	83	5180	2.08	1.80	1.60
Muskoka	101	95	74	4837	2.09	1.96	1.53
Ottawa	99	90	70	4673	2.12	1.93	1.50
Kingston	92	83	67	4266	2.16	1.95	1.57
Toronto	88	80	69	4082	2.16	1.96	1.69
London	87	78	63	4068	2.14	1.92	1.55
Simcoe	84	74	61	3962	2.12	1.87	1.54
Windsor	77	69	54	3590	2.14	1.92	1.50

FIGURE 1

MAP OF EFFECT OF WEATHER ON ANNUAL ENERGY SAVINGS FACTOR (BUNGALOW, WALL CAVITY: 0 TO 2.1 RSI)

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APPENDIX

Descriptions of Typical Houses, Basic Case

A. **Bungalow**

built to 1970 Gold Medallion Standard
140 m^2 (10 m x 14 m)
full basement, 0.61 m above grade

windows: 14 m^2 total, double glazed (RSI 0.35), 4 per face:

2 on first floor: 1 m high x 1.35 m wide with 0.3 m overhang and 0.3 m header height
2 in basement: 0.4 m high x 1.0 m wide with 0.3 m overhang and 2.5 m header height

doors: 2.03 m high x 0.81 m wide, 1 on each long face, RSI 0.45

Insulation:

	ceiling	walls	basement walls		basement floor
			above grade	to 0.61 m below grade	
RSI	2.52	2.11	1.66	1.23, insulation only	uninsulated

Ventilation: 0.4 ac/h natural infiltration

Temperatures: 20°C except 18°C in basement

B. **Two Storey**, as for bungalow except as noted

built to 1985 Ontario Building Code

202.3 m^2 (8.5 m x 11.9 m)

Windows: 20.23 m^2 total, 6 per face:

2 each on second and first floors: 0.8 m high x 1.31 m wide
header heights as appropriate for the storey

Insulation:

	ceiling	walls	basement walls		basement floor
			above grade	to 0.61 m below grade	
RSI	5.64	2.11	2.11	1.69, insulation only	uninsulated

C. **Big Bungalow**, scaled up from A by a factor of 2